

**REPORT DOCUMENTATION PAGE**Form Approved  
OMB No. 0704-0188

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<b>1. REPORT DATE (DD-MM-YYYY)</b>		<b>2. REPORT TYPE</b> Technical Papers		<b>3. DATES COVERED (From - To)</b>	
<b>4. TITLE AND SUBTITLE</b>				<b>5a. CONTRACT NUMBER</b>	
				<b>5b. GRANT NUMBER</b>	
				<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>				<b>5d. PROJECT NUMBER</b> 3059	
				<b>5e. TASK NUMBER</b> RD3D	
				<b>5f. WORK UNIT NUMBER</b> 346011	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				<b>8. PERFORMING ORGANIZATION REPORT</b>	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b>  Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b>	
				<b>11. SPONSOR/MONITOR'S NUMBER(S)</b>  AFRL-PR-ED-TP-1998-113	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b>  Approved for public release; distribution unlimited.					
<b>13. SUPPLEMENTARY NOTES</b>					
<b>14. ABSTRACT</b>					
<b>20030127 170</b>					
<b>15. SUBJECT TERMS</b>					
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>  A	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b> Leilani Richardson
<b>a. REPORT</b>  Unclassified	<b>b. ABSTRACT</b>  Unclassified	<b>c. THIS PAGE</b>  Unclassified			<b>19b. TELEPHONE NUMBER</b> (include area code) (661) 275-5015

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## MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO)

10 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-113  
C.W. Beckman, R.L. Geisler "The History of the BATES Motor at RPL

AIAA slides

(Statement A)



# THE HISTORY OF THE BATES MOTOR AT RPL

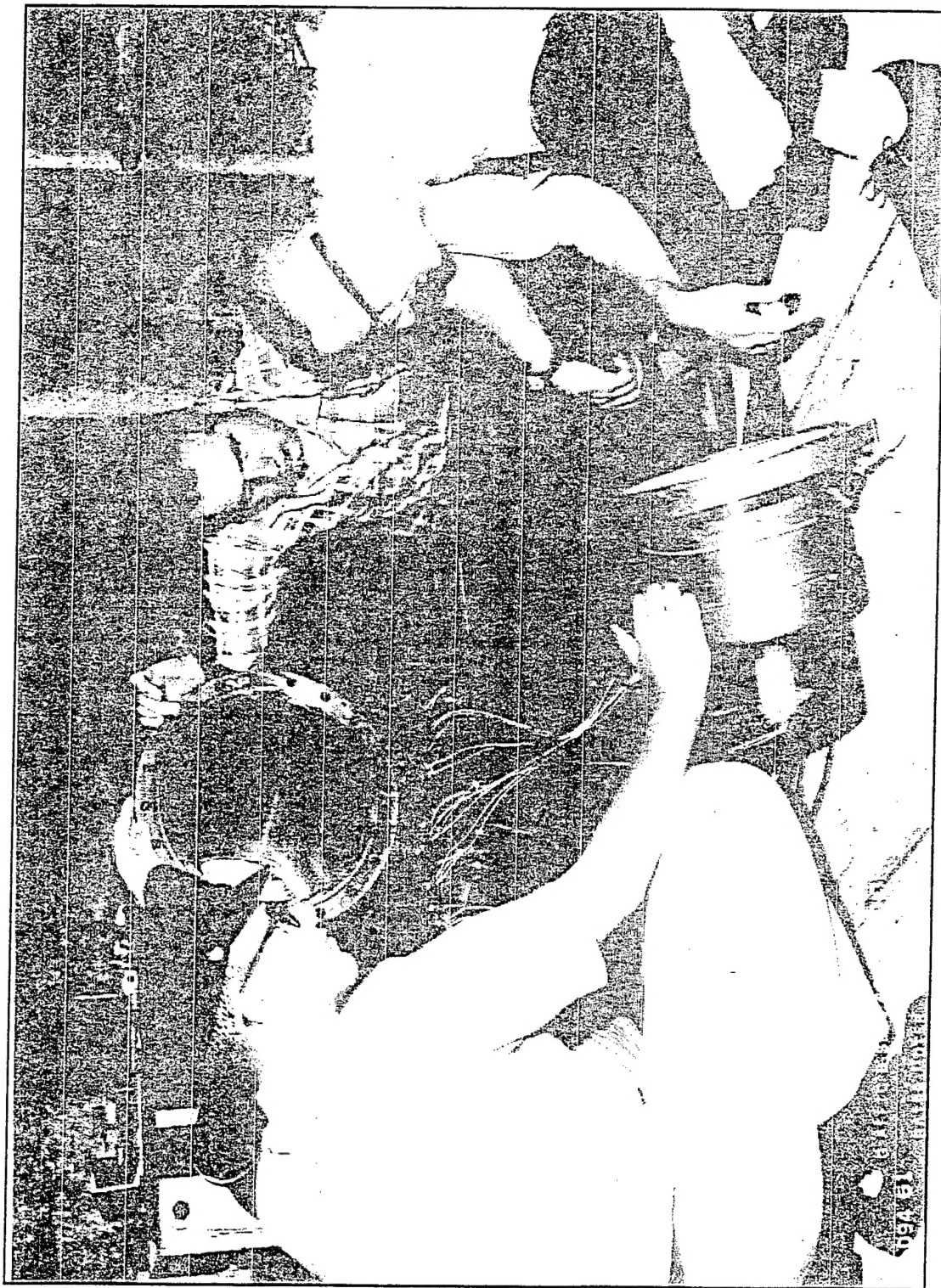
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CHARLES W. BECKMAN  
AIR FORCE RESEARCH LABORATORY  
ROBERT L. GEISLER  
GEISLER ENTERPRISES

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# INITIAL BATES FIRING - Sept 1961





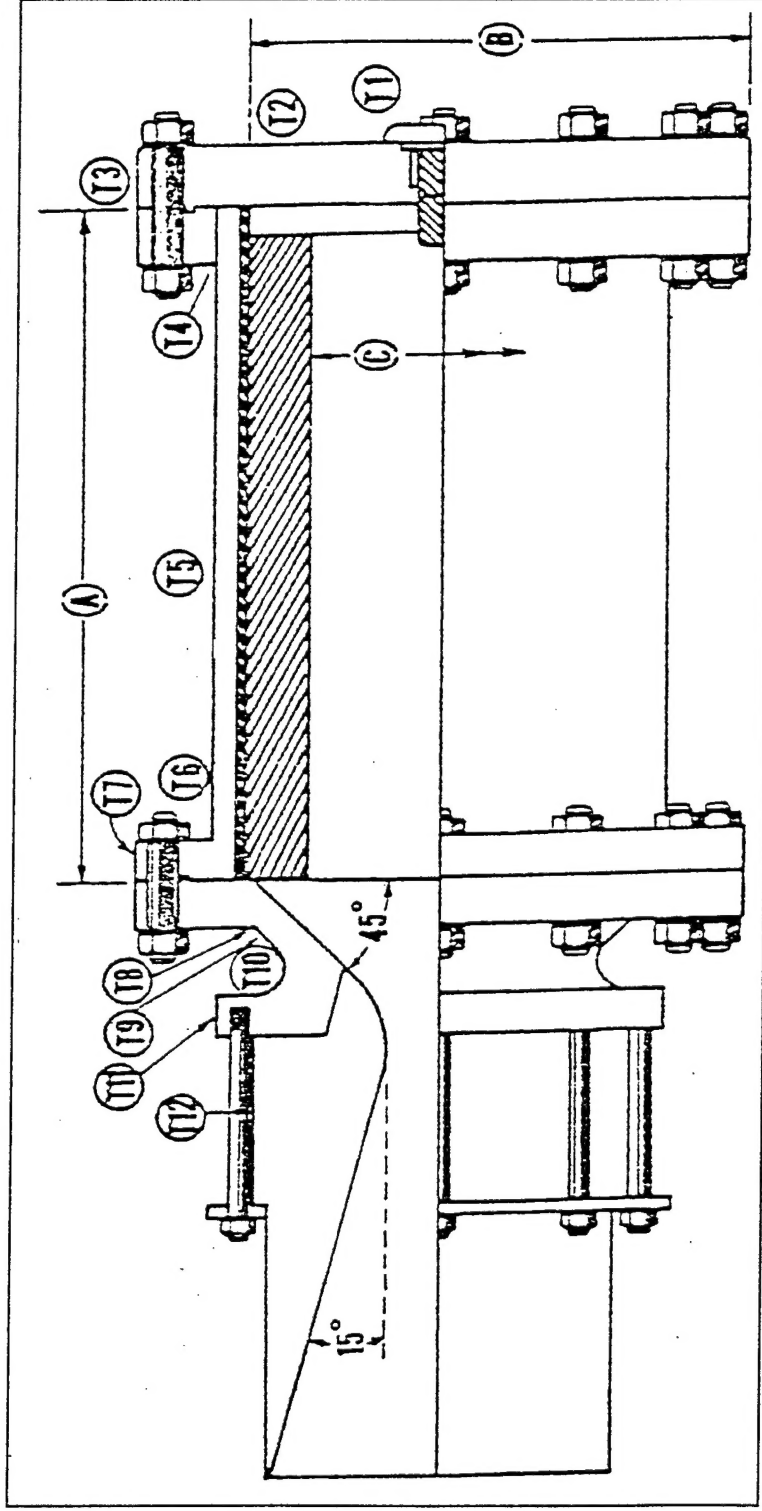
# BATES

## Ballistic Test Evaluation and Scaling

A highly accurate test motor system for ballistic prediction, assessment and comparison.



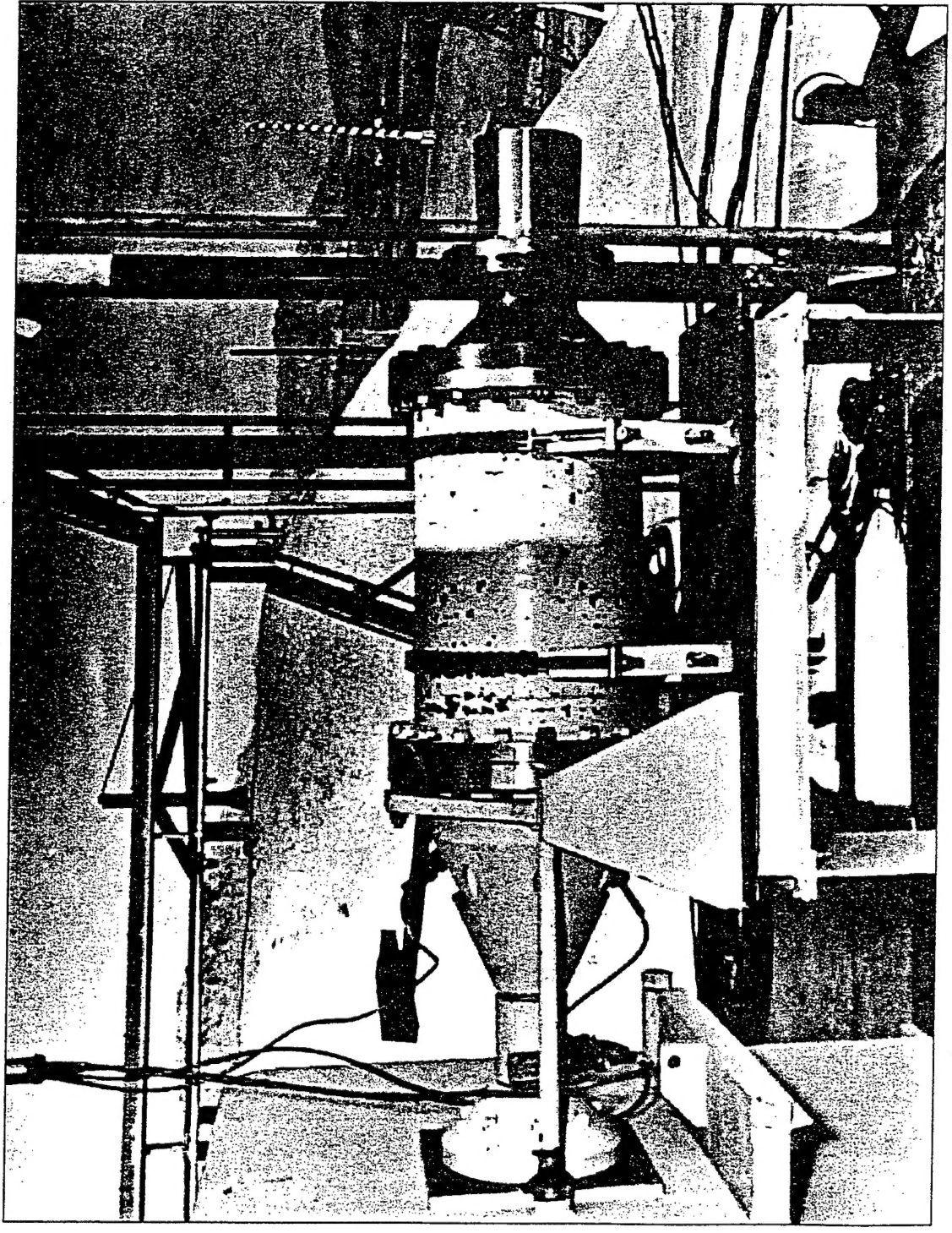
# 15-lb and 70-lb BATES Motor Design



Motor size	15-pound	70-pound
Pressure (psi)	1000.	1000.
Nozzle Diameter <sup>units</sup>	1.	2.
Gas Residence Time (msec)	8.	17.
Grain Length (in) (A)	12.	20.
Grain Outside Diameter (in) (B)	6.75	12.
Grain Port Diameter (in) (C)	4.6	8.



# Standard 70-lb BATES Motor

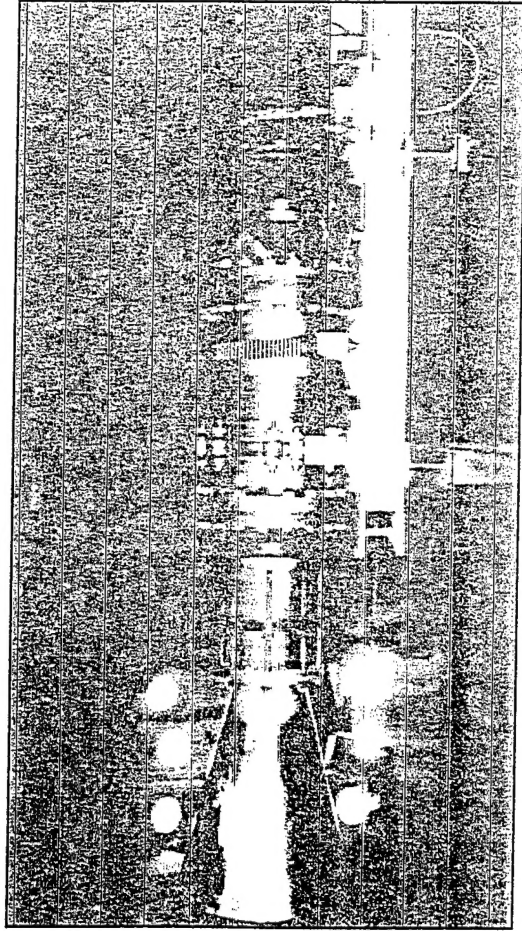




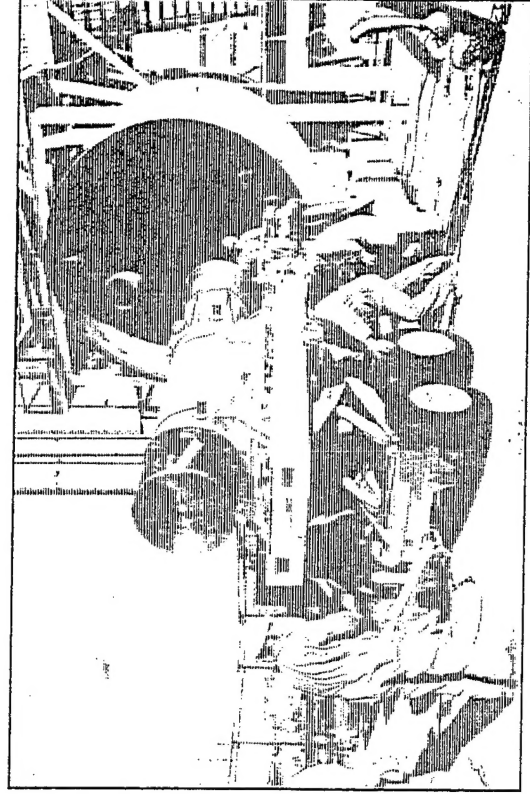


# Vacuum Ballistics Testing

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70 Pound Reusable  
BATES Motor

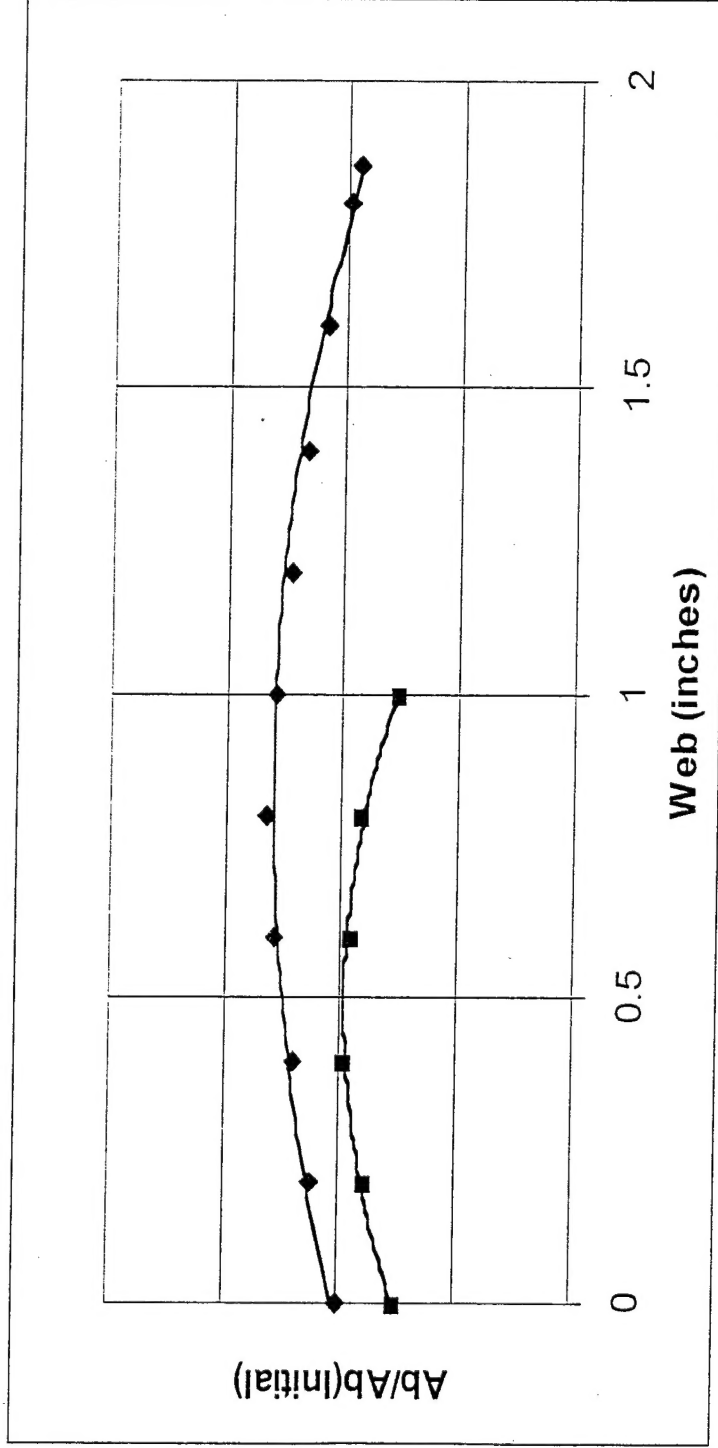


Super BATES Reusable  
Motor





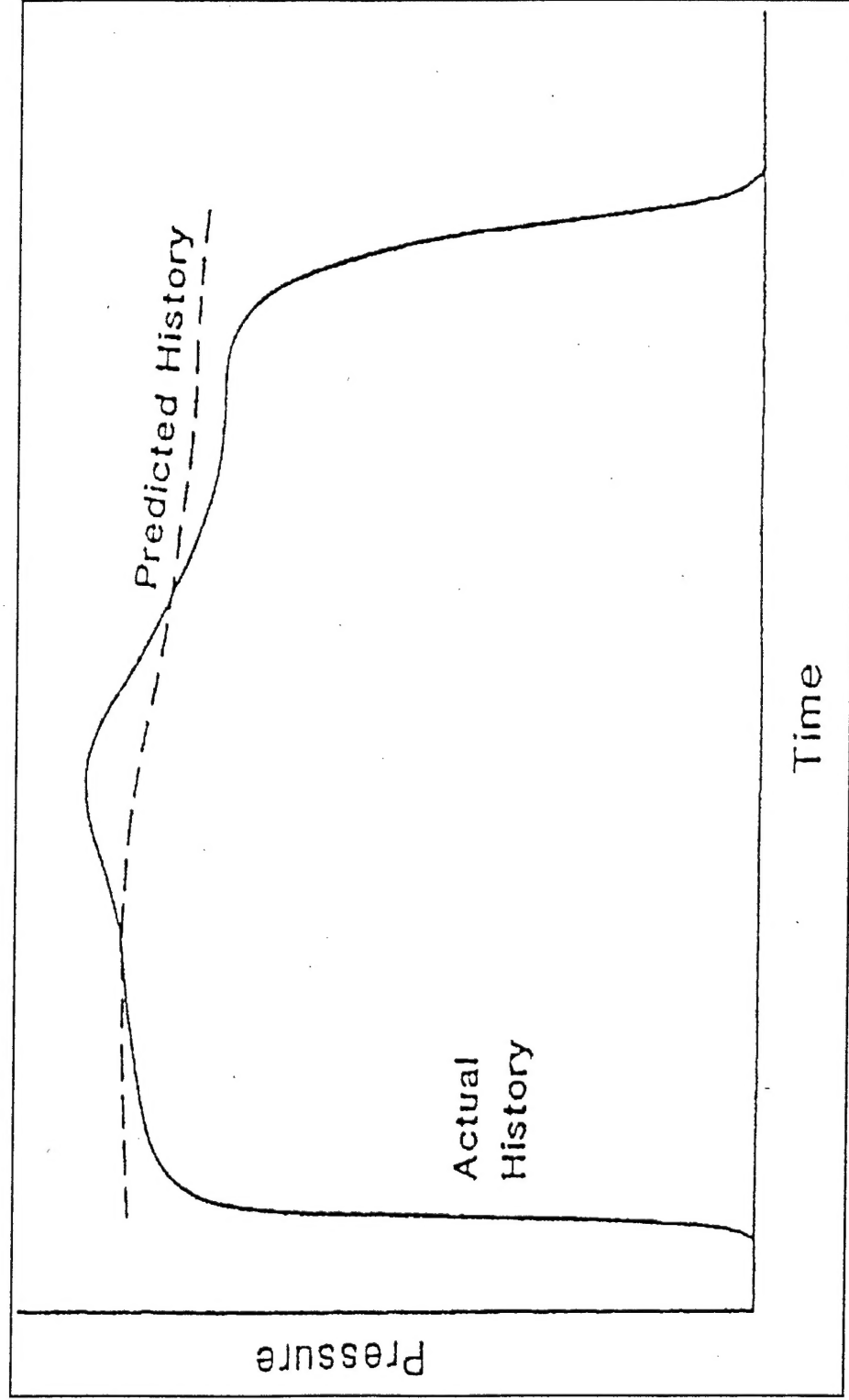
# 15-lb and 70-lb BATES Burnback History



Motor size 15-pound/70-pound  
Neutrality (max/ave/min) 1.01/1.00/0.97  
Port/Throat Ratio ~30



# Ballistic Anomaly Phenomena





# BATES DELIVERED SPECIFIC IMPULSE

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## ESTIMATED ERROR

### + 0.25 seconds

70-pound thrust accuracy + 0.10 %

15-pound thrust accuracy + 0.25 %

3 70-pound firings required for this precision

6 15-pound firings required for this precision

### + 0.10 seconds

6 70-pound firings required for this precision

9 15-pound firings required for this precision



# BATES Test History

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## Motor Firings

Approximately 4000 test firings

## Propellant Evaluations

Approximately 400 formulations evaluated



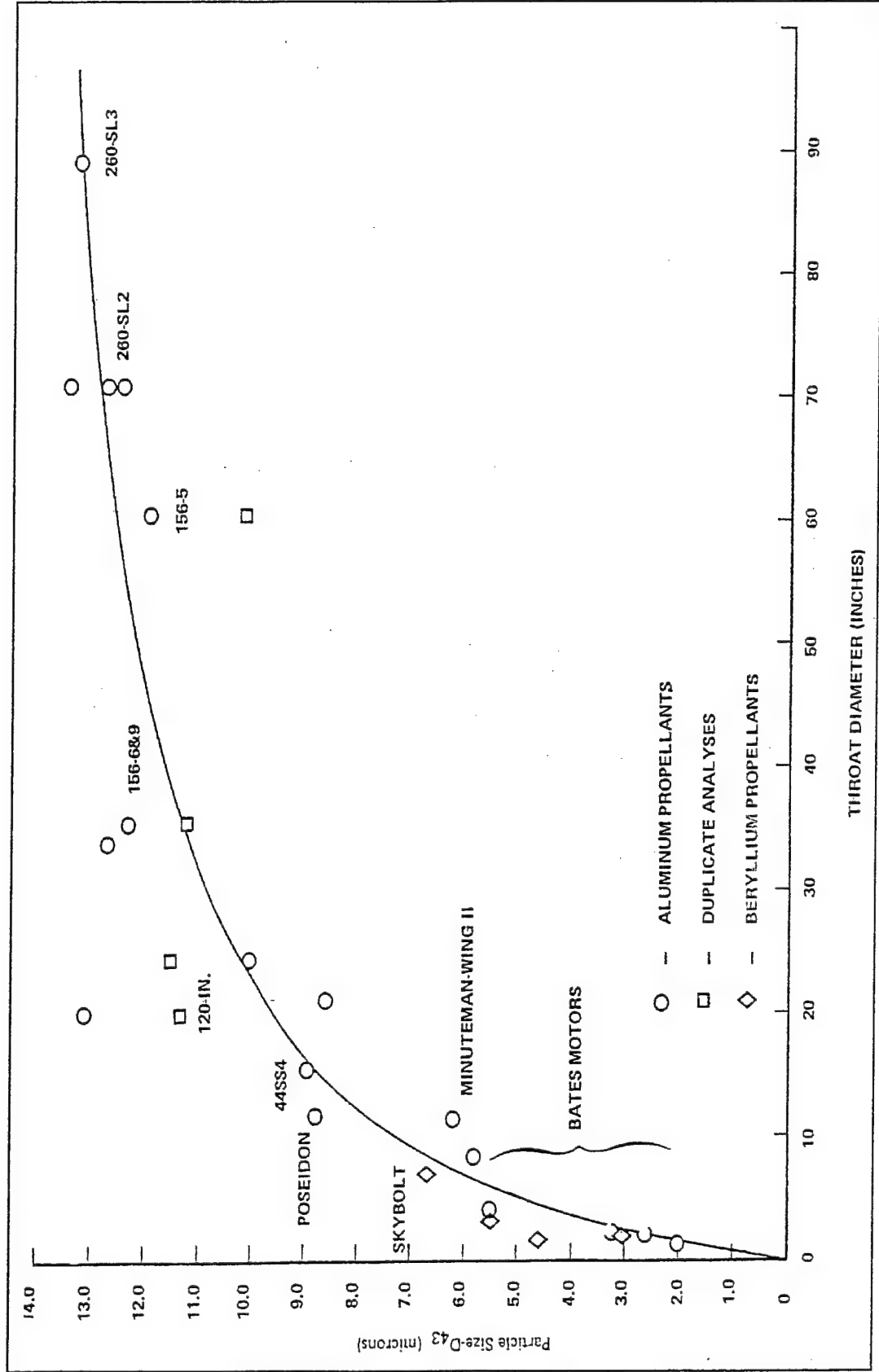
# **SPECIFIC IMPULSE EFFICIENCY INFLUENCES**

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- **COMBUSTION EFFICIENCY**
- **HEAT LOSS**
- **DIVERGENCE LOSSES**
- **TWO-PHASE FLOW LOSSES**
  - **MULTIPHASE MOMENTUM LOSSES**
  - **MULTIPHASE TEMPERATURE NON-EQUILIBRIUM**
- **CHEMICAL RECOMBINATION LOSSES**
- **FRICTIONAL LOSSES**

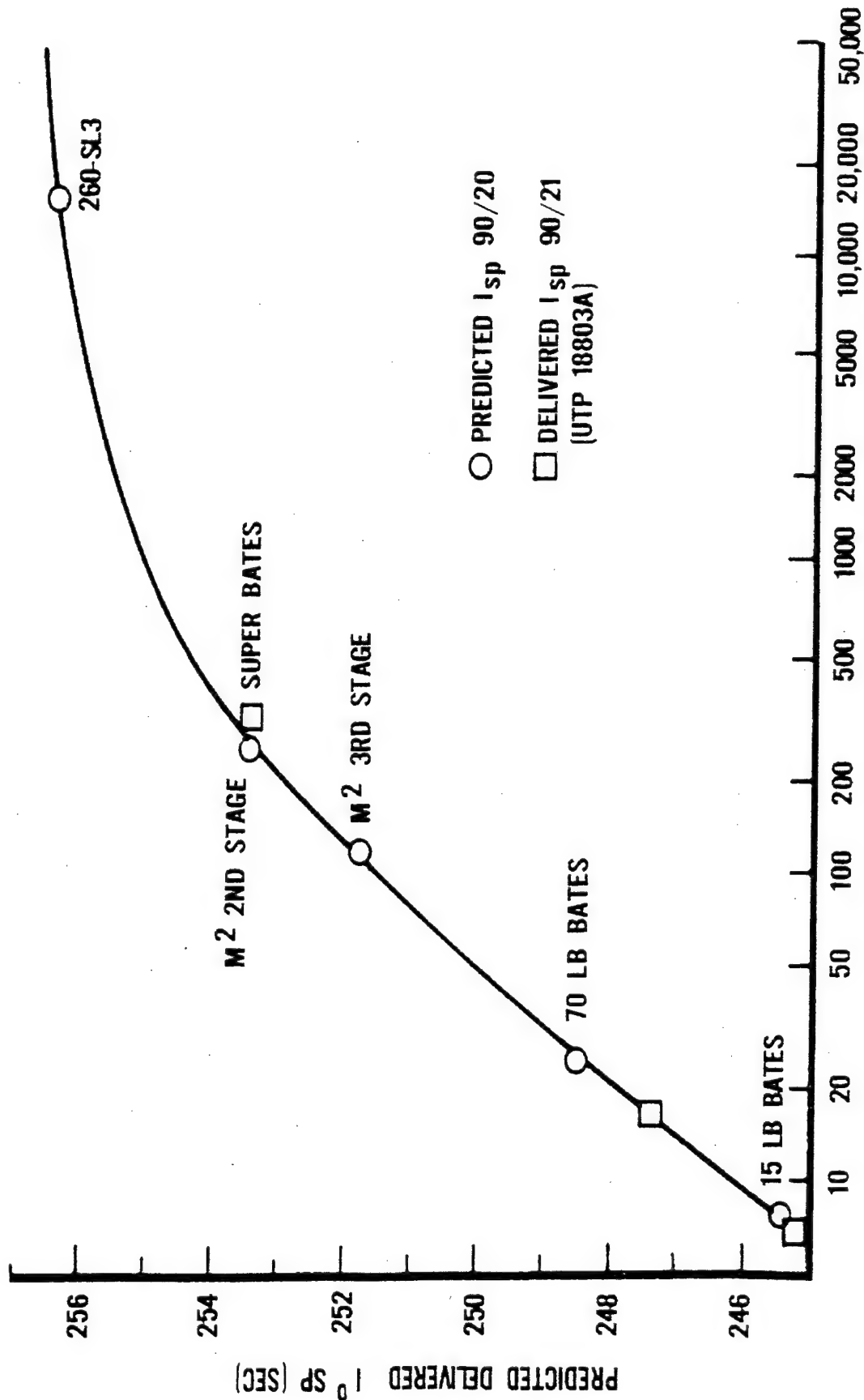


# Particle Size vs Throat Diameter





# Delivered Isp vs Mass Flow Rate







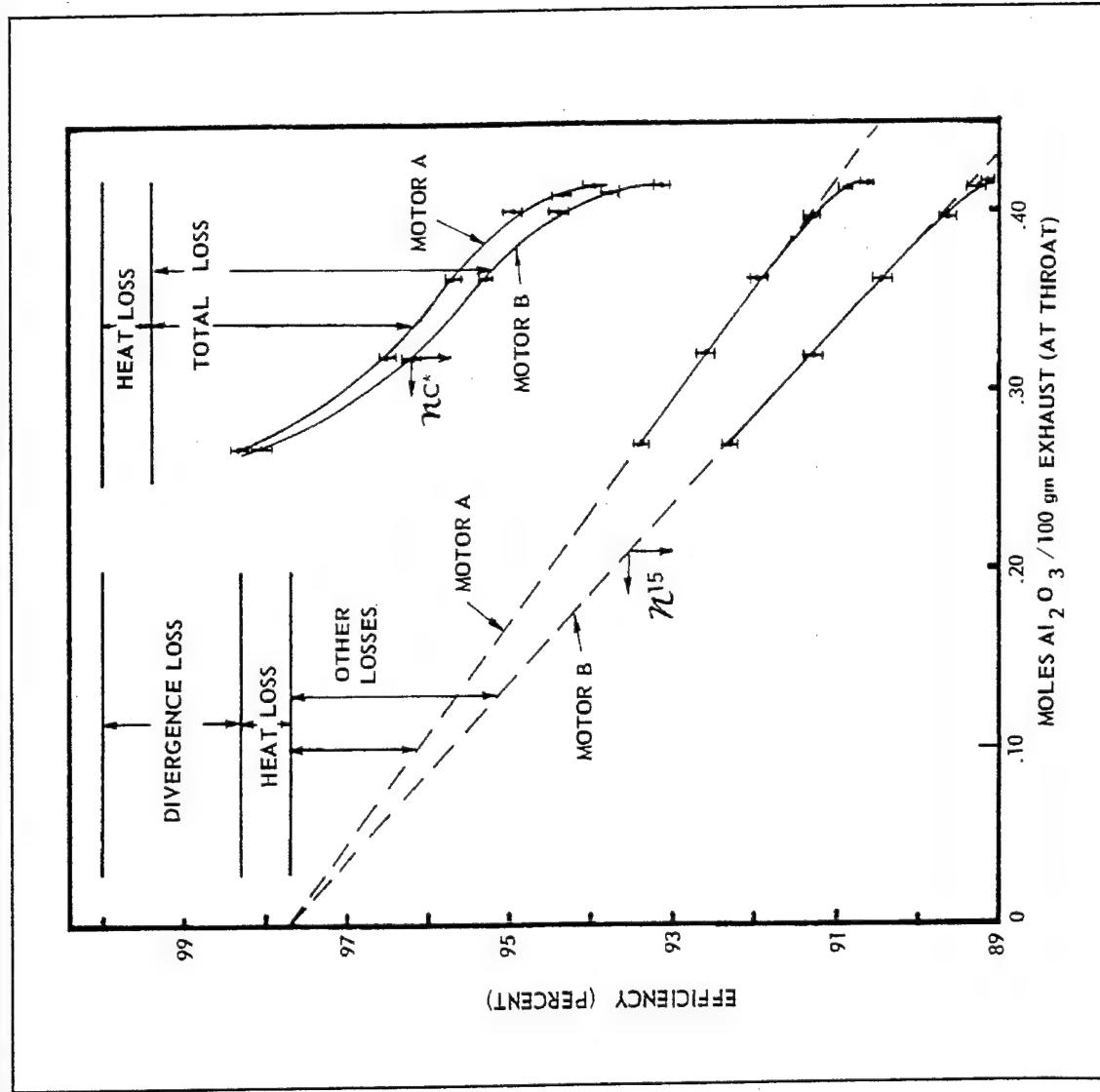
# Varying Aluminum Propellant Formulations

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Wt% Al	15.	18.	21.	24.	27.	30.
Wt% AP	75.	72.	69.	66.	63.	60.
Wt% HTPB	10.	10.	10.	10.	10.	10.
Rb 1000 psia	0.56	0.55	0.56	0.46	0.51	0.50
$\eta^{15}$ (ISP)15-lb	92.30	91.27	90.48	89.59	89.11	88.89
$\eta^{15}$ (ISP)70-lb	93.38	92.84	92.03	91.31	90.92	90.51
Tc(K)@1000psi	3602.	3682.	3746.	3784.	3787.	3743.
T*(K) no Al	2859.	2791.	2705.	2605.	2494.	2376.
Moles/100 gm.	0.269	0.319	0.362	0.396	0.413	0.415
Al <sub>2</sub> O <sub>3</sub> at Thrt						



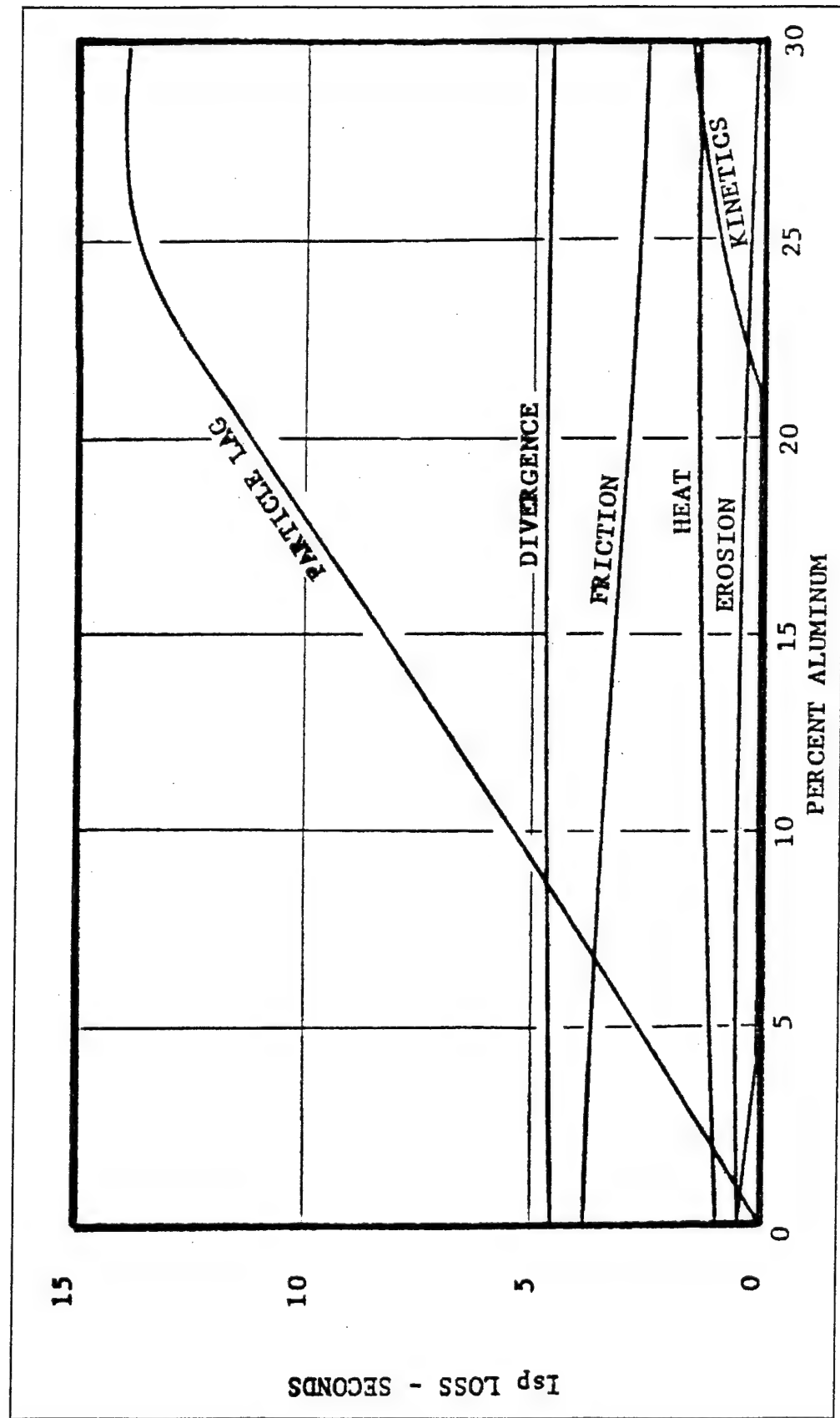
# Initial BATES Scaling Approach





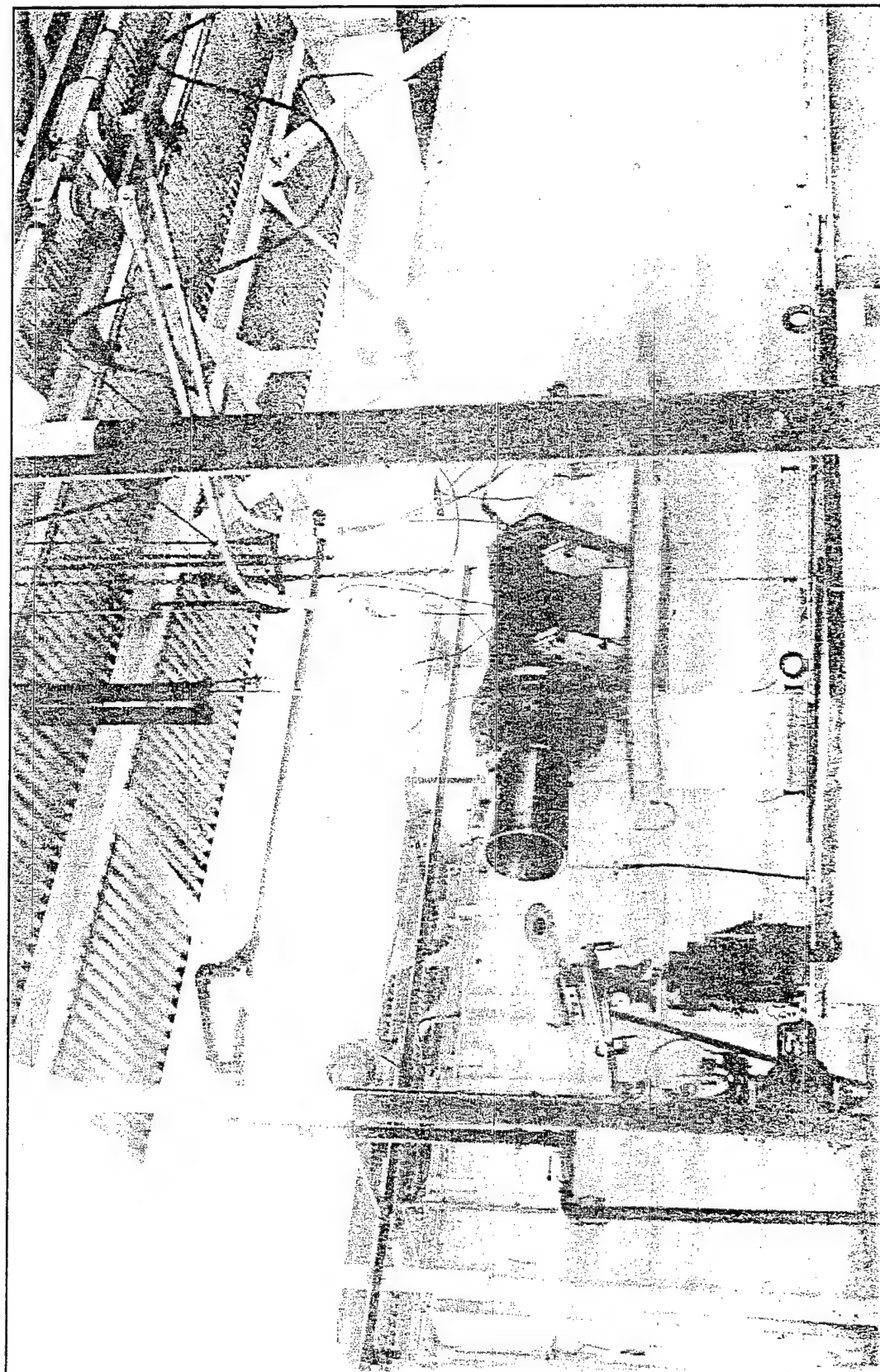
# Thrust Losses Occurring in the 70-lb BATES Motor

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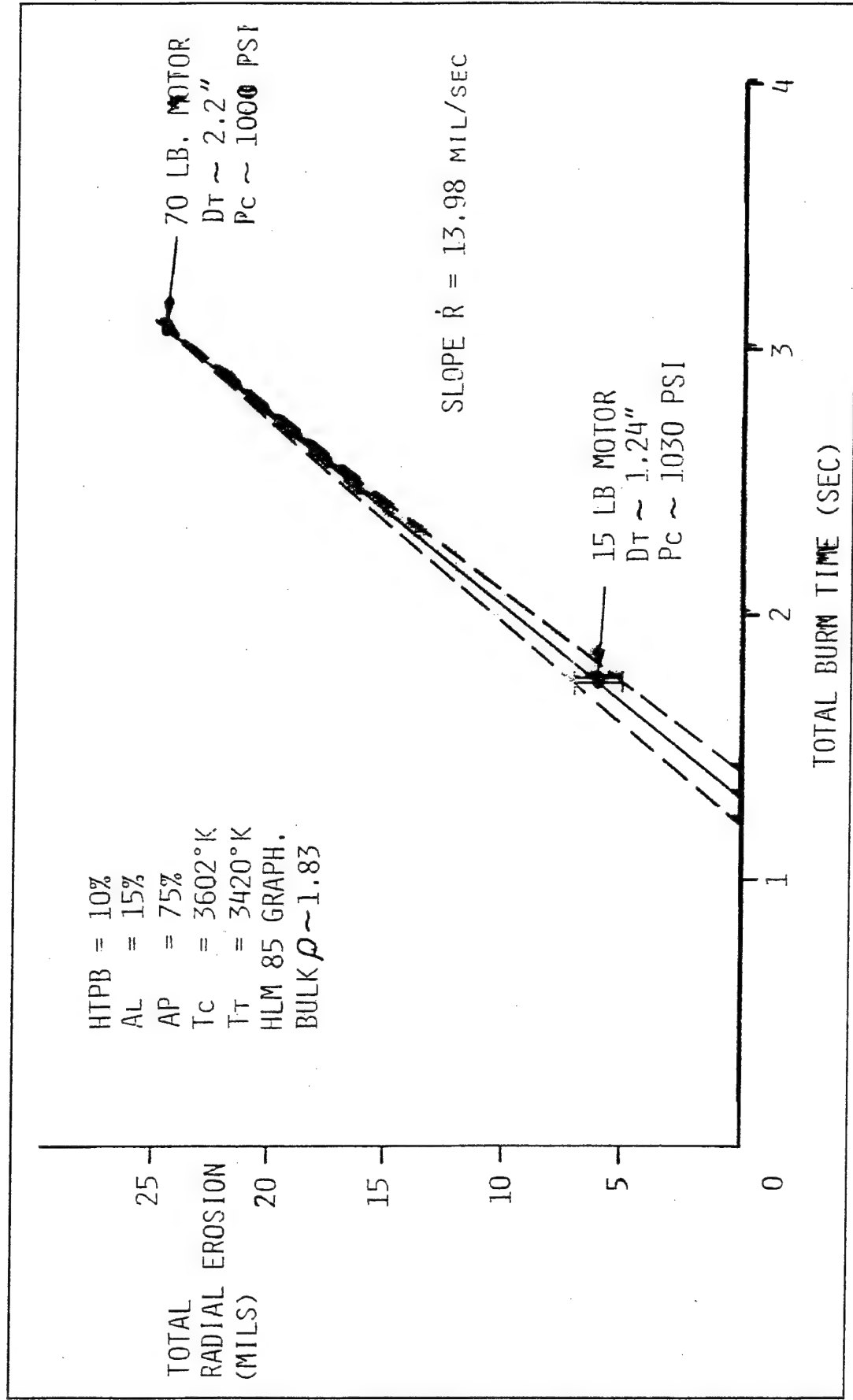


# BATES Laser Particle Size Measurements



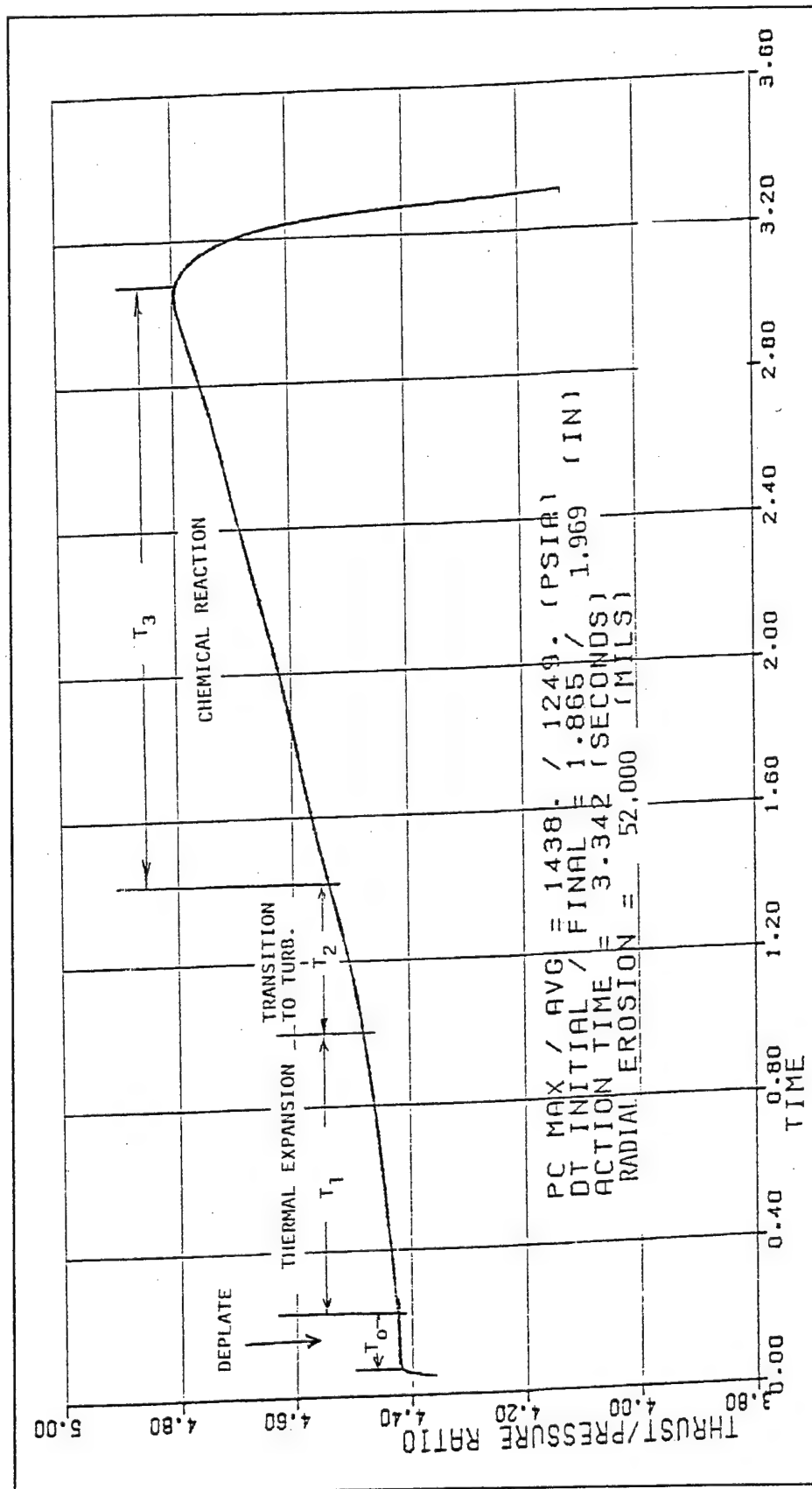


# Initial Recession Analysis



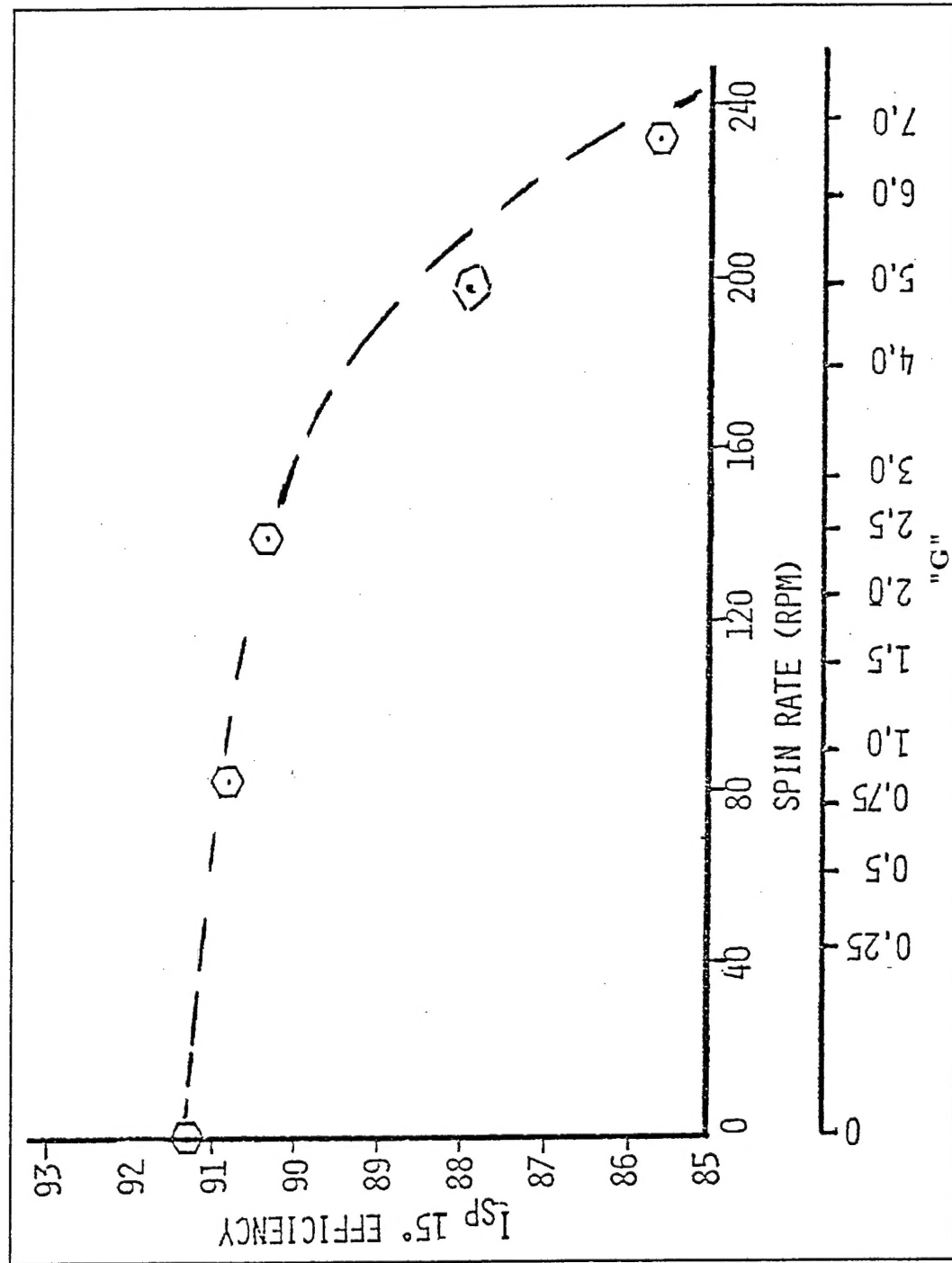


# Thrust/Pressure Analysis





# Isp Efficiency Vs Spin "G" Level (70 lb BATES)

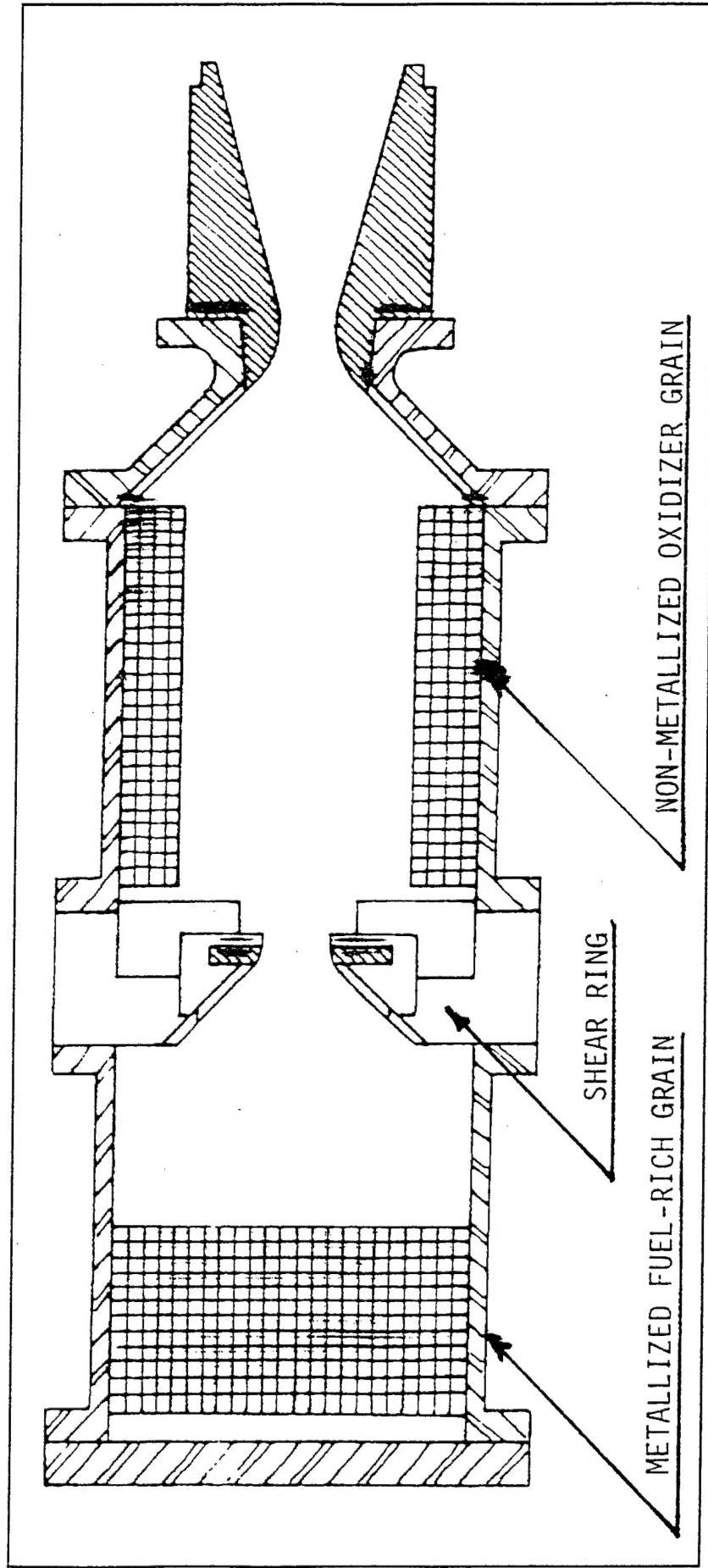






# Dual Chamber Staged Combustion Feasibility Motor

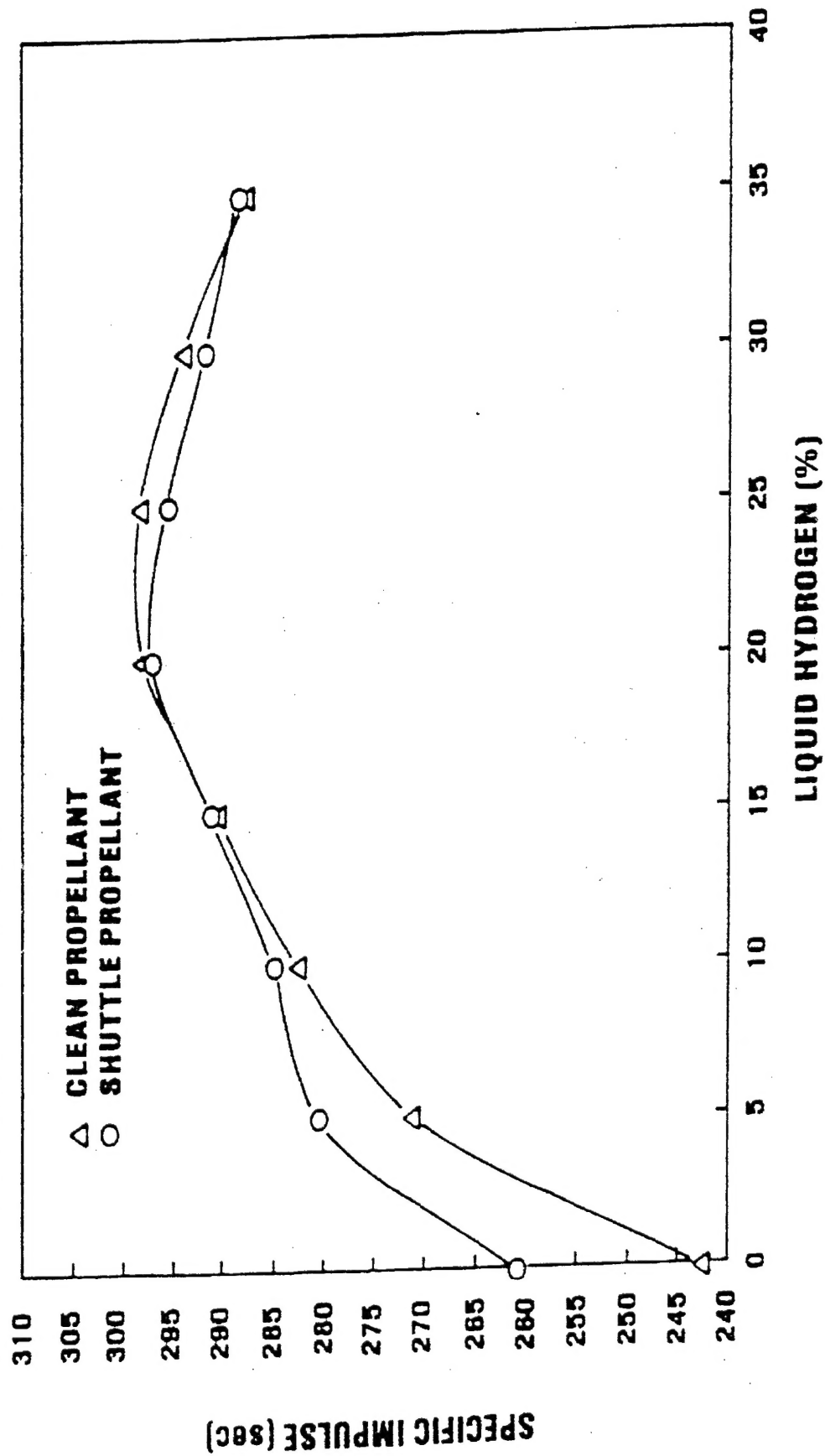
alaa1 ppt





# Performance Increase from Hydrogen Augmentation

PERFORMANCE INCREASE OF SOLID MOTORS





# Summary

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- **BATES is an Invaluable Assessment Tool**
    - Provides Precision Measurements
    - Simple and Analyzable Hardware
    - Adaptable to Tactical, Strategic or Space Needs
- Irreplaceable Propellant and Ballistic Database**